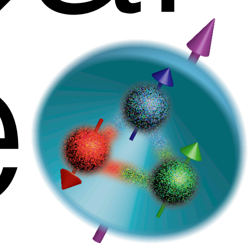
Thomas Burton

DIS 2014
XXII International Workshop on Deep-Inelastic Scattering ad Related Subjects

Warsaw
28th April- 2 May 2014

BROOKHAVEN NATIONAL LABORATORY

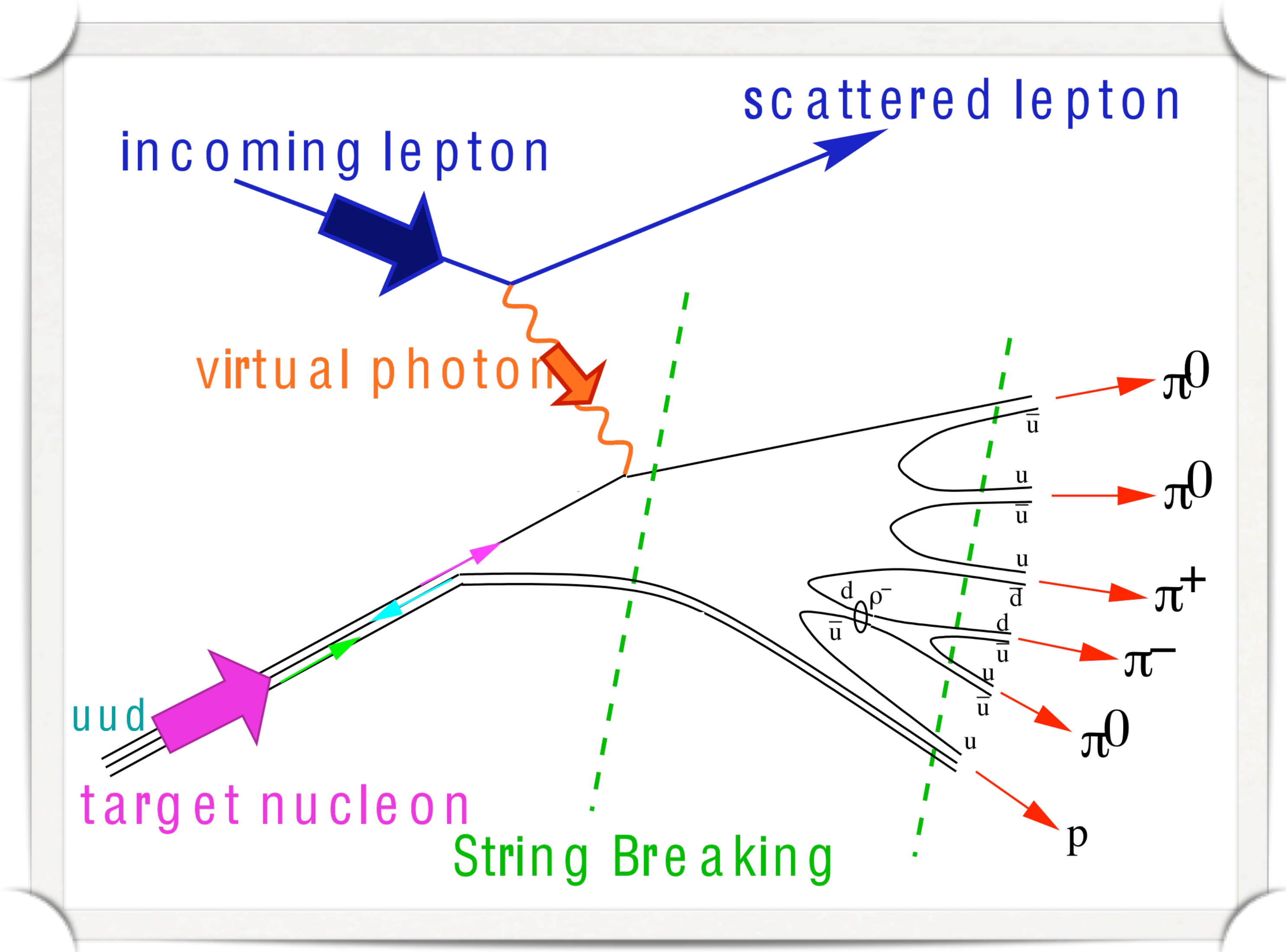
charged current **DIS** on longitudinally po↓ar↑sed nuclens at an **EIC**

Overview

- Charged current DIS with polarised nucleons
- CC DIS and electron-ion collider (EIC)
- Event simulation with radiative corrections
- Detector effects and kinematic reconstruction
- Asymmetry results

PRD **88** 114025 (2013)

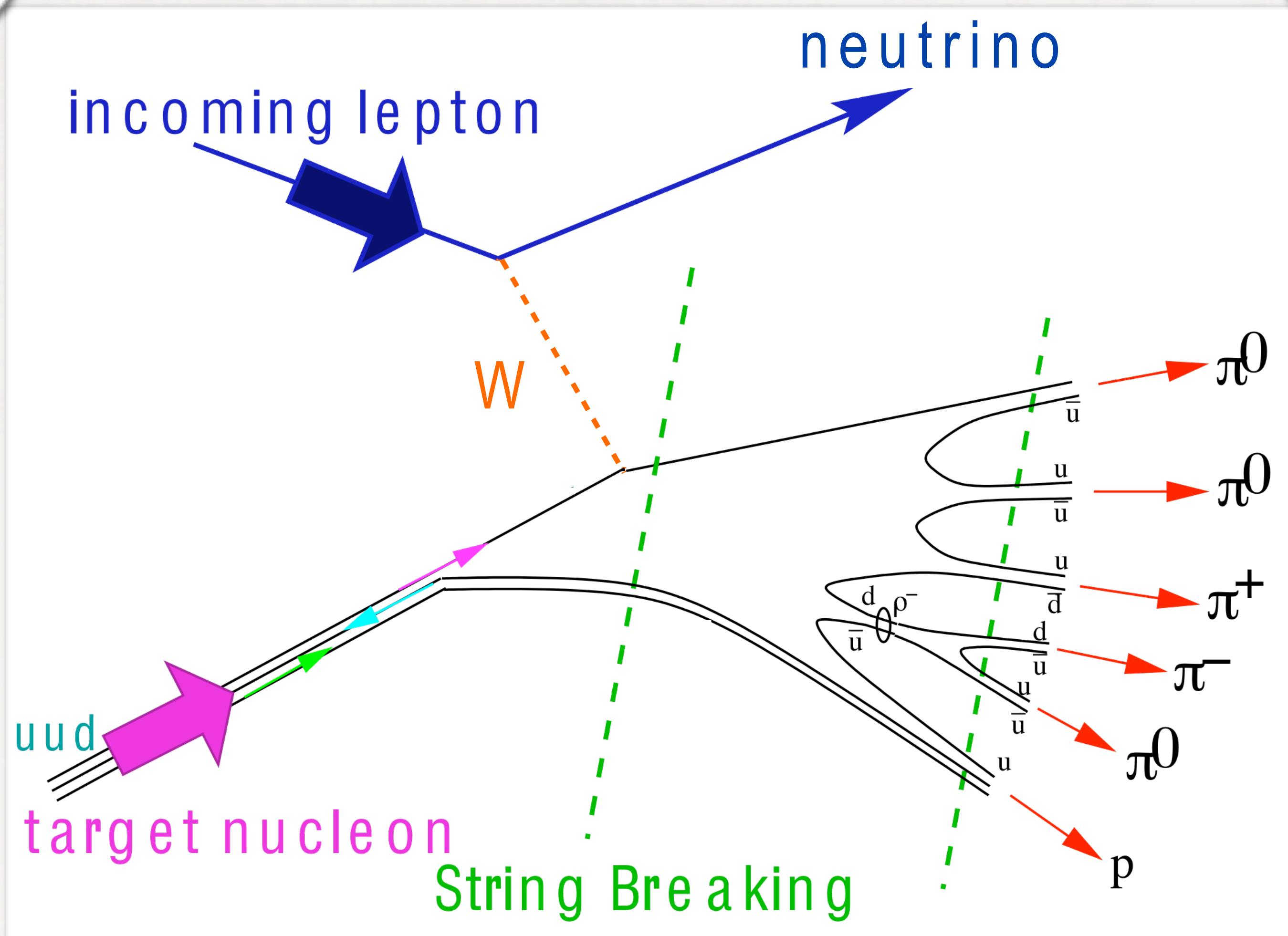
SIDIS vs. charged current DIS



- Both allow **flavour separation**
- CC differs in:
  - no **fragmentation functions**
  - accesses higher Q^2
  - different flavour combinations

Want to do both because they
- offer **complementary information**
- access different **kinematic regimes**

SIDIS vs. charged current DIS



- Both allow **flavour separation**
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$$\frac{d^2\Delta\sigma^{W^-,N}}{dxdy} = \frac{2\pi\alpha_{em}^2}{xyQ^2}\eta[2Y_- x g_1^{W^-,N} - Y_+ g_4^{W^-,N} + y^2 g_L^{W^-,N}]$$

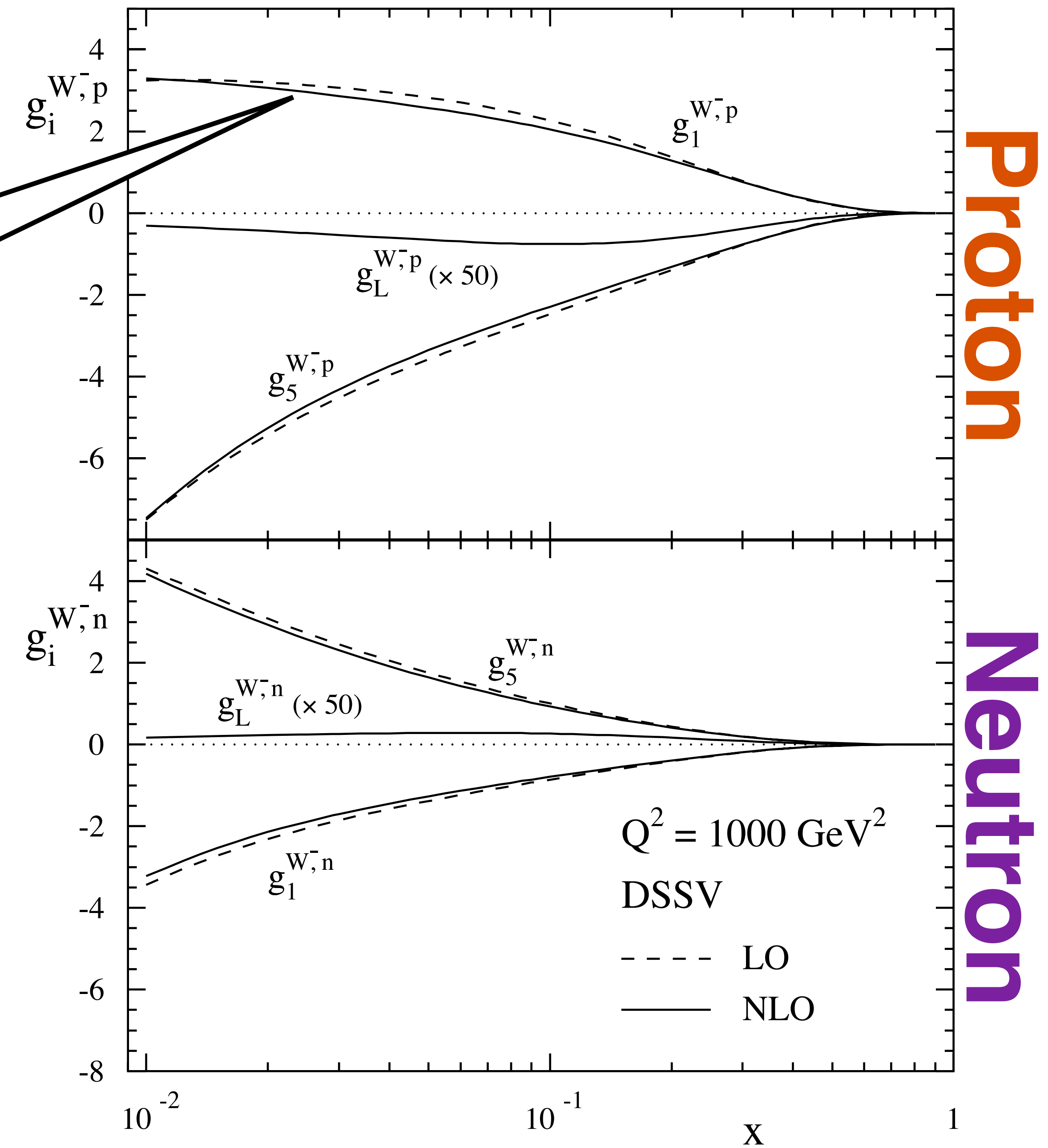
$$g_L \equiv g_4 - 2xg_5$$

CC structure functions

$$g_1^{W^-,p}(x) = \Delta u(x) + \Delta\bar{d}(x) + \Delta c(x) + \Delta\bar{s}(x),$$

$$g_5^{W^-,p}(x) = -\Delta u(x) + \Delta\bar{d}(x) - \Delta c(x) + \Delta\bar{s}(x)$$

NLO corrections are modest



- How can we measure **polarised CC DIS**?
  - need a **new machine**

Structure functions

Charged current DIS at an EIC

Electron-Ion Collider (EIC)

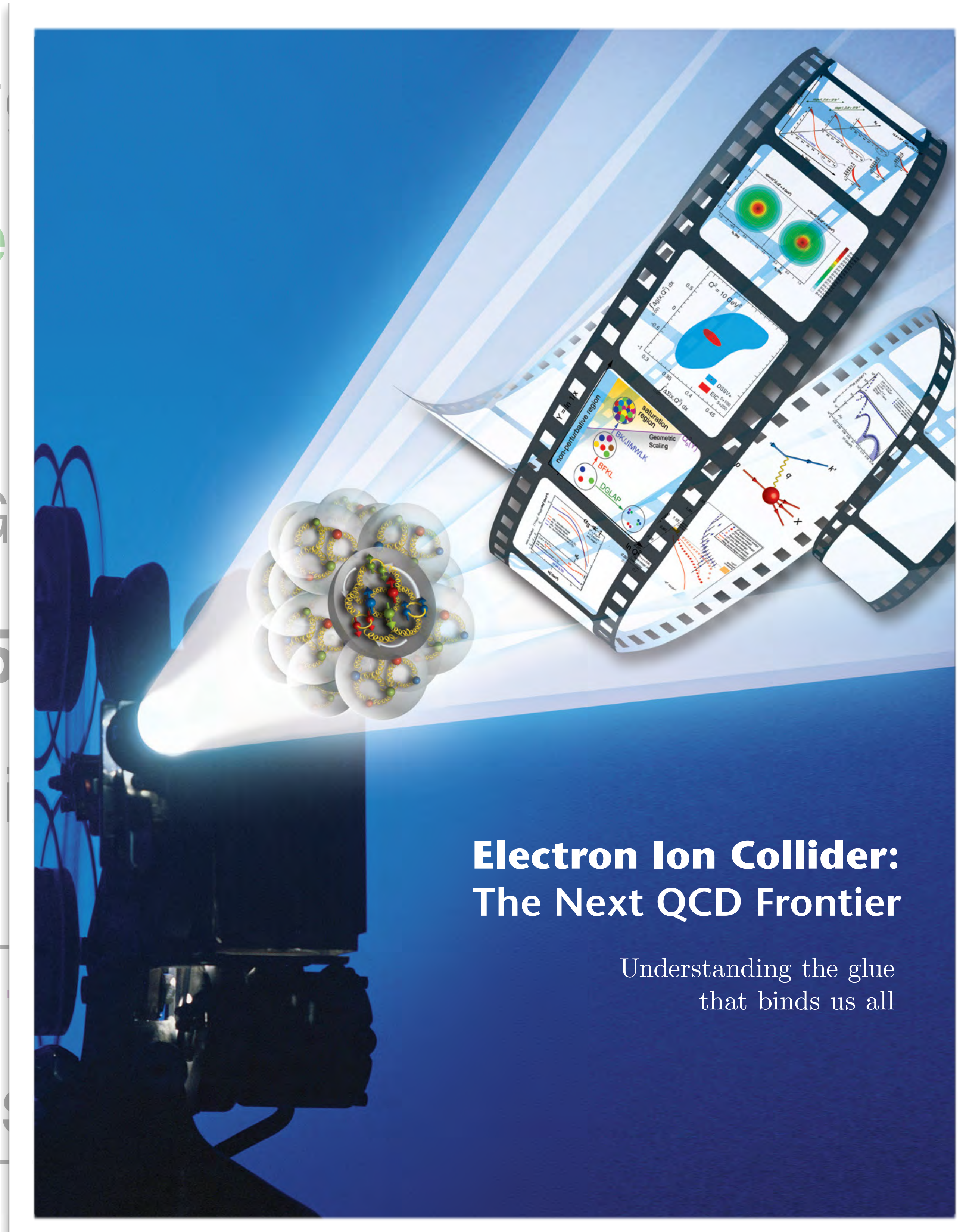
- High energy **electron**-**hadron** collider
- Assume **eRHIC** baseline performance here
  - Beams: **p**↑, "**n**↑" (He^3) & nuclei
  - **10-20** GeV **electrons**
  - up to **250** GeV **protons**
  - luminosity: ~ $\mathbf{10^{33}}$ $cm^{-2}\ s^{-1}$

See talks by
E. Aschenauer
& JH Lee
& P. Nadel-
Turonski

Use **10** $\mathbf{fb^{-1}}$ (~ 1 year of running) as a realistic "chunk" of data for our study

Electron-Ion Collider (EIC)

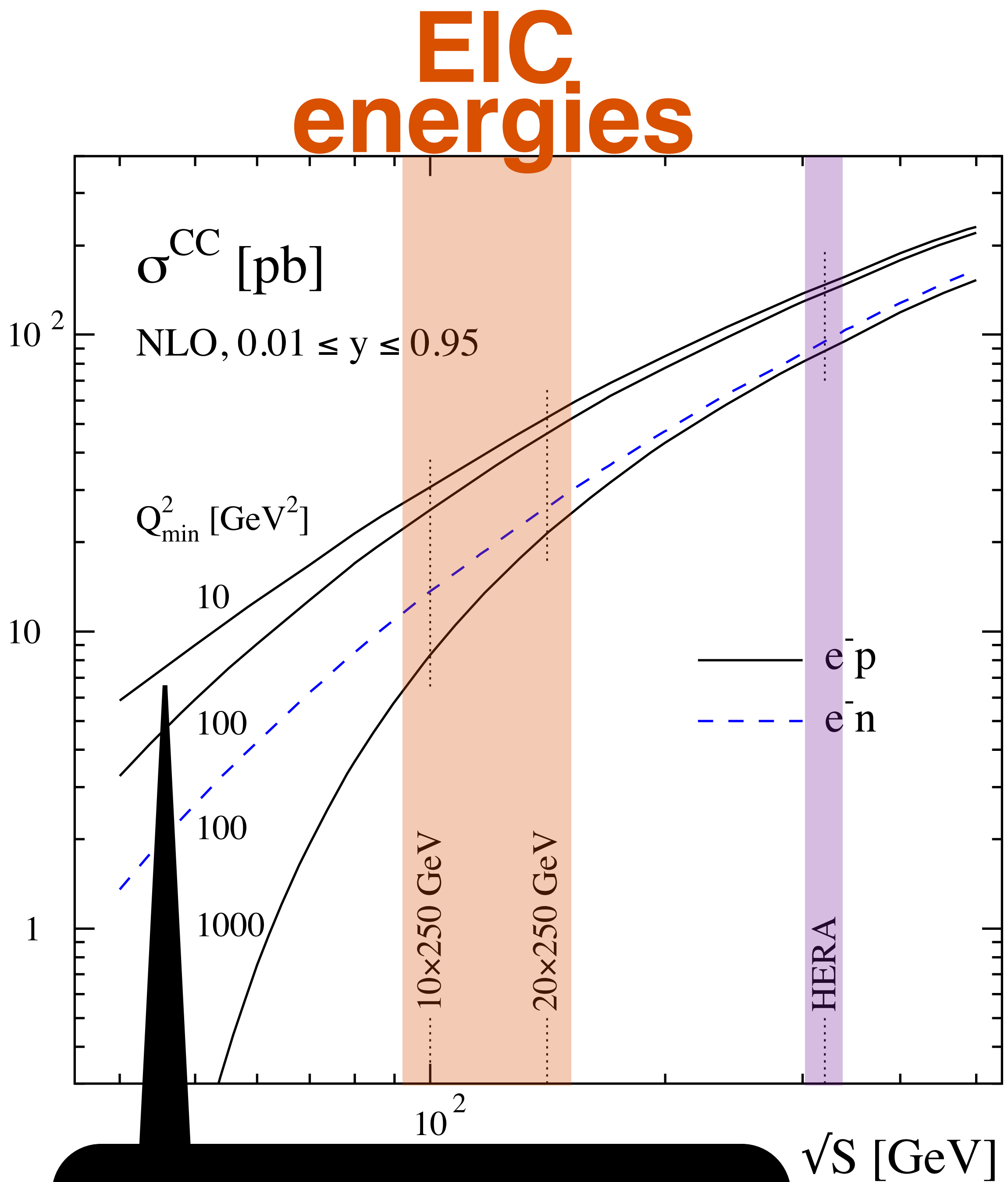
- High ener
- Assume e … here
  - Beams:
  - **10-20** G
  - up to **25**
  - luminosi



talks by
schenauer
JH Lee
P. Nadel-
uronski

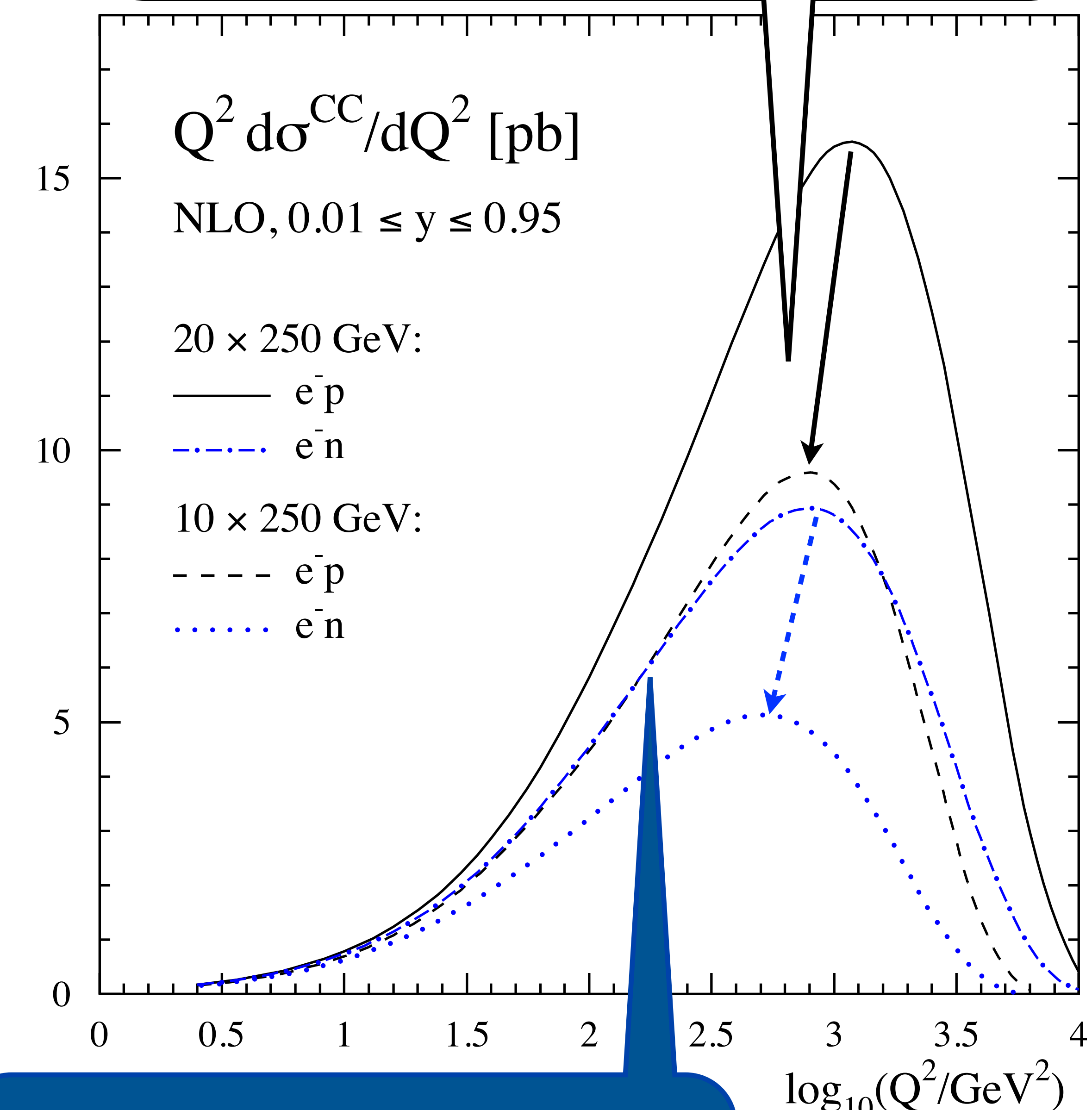
Use … as a
reali … tudy

CC DIS cross section

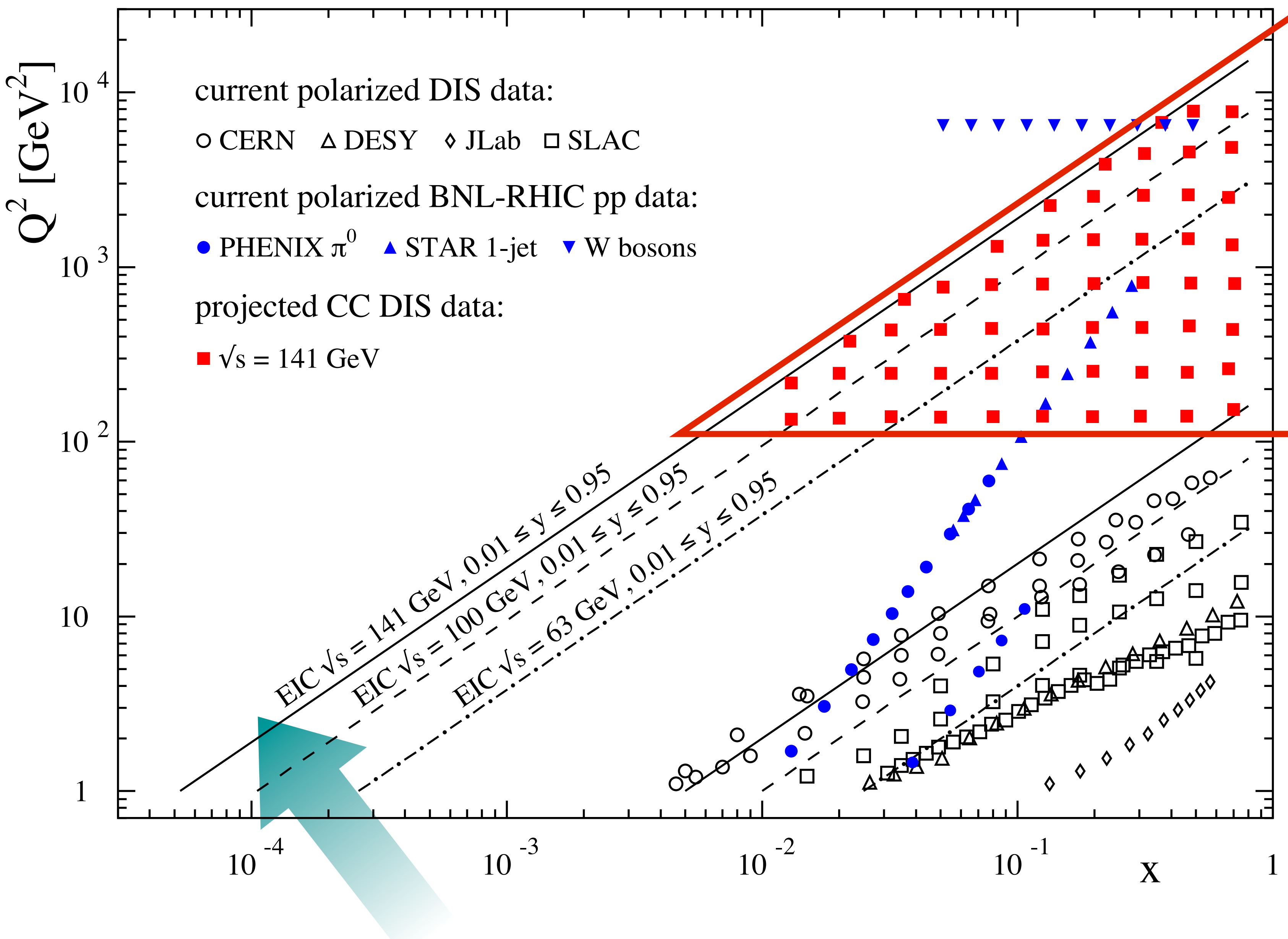


σ depends little on Q^2_{min} for $Q^2_{min} < M_W^2$

Still feasible at lower electron energy



n ~ 2x lower than p
u(x) < d(x)



Up to **x100** range in Q^2 at given x
→ **QCD evolution**

Most σ > 100 GeV^2

Limit ourselves to here for this study

Higher energy better for

- cross section and
- kinematic reach

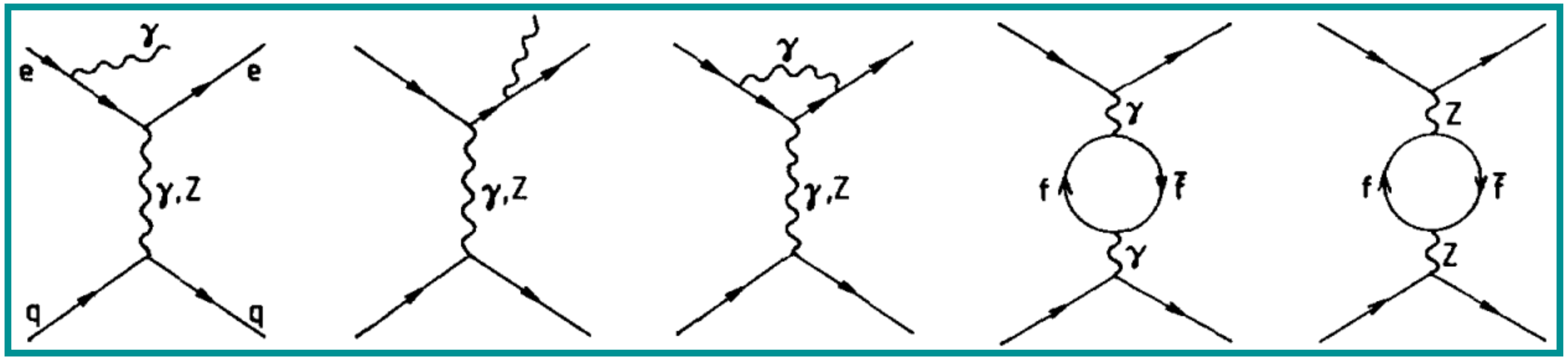
Kinematic coverage

Event simulation with radiative corrections

DJANGOH

K. Charchula, G. A. Schuler,
and H. Spiesberger,
Comput. Phys. Commun. 81, 381 (1994).

- DIS event generator
  - includes QED and QCD **radiative effects**

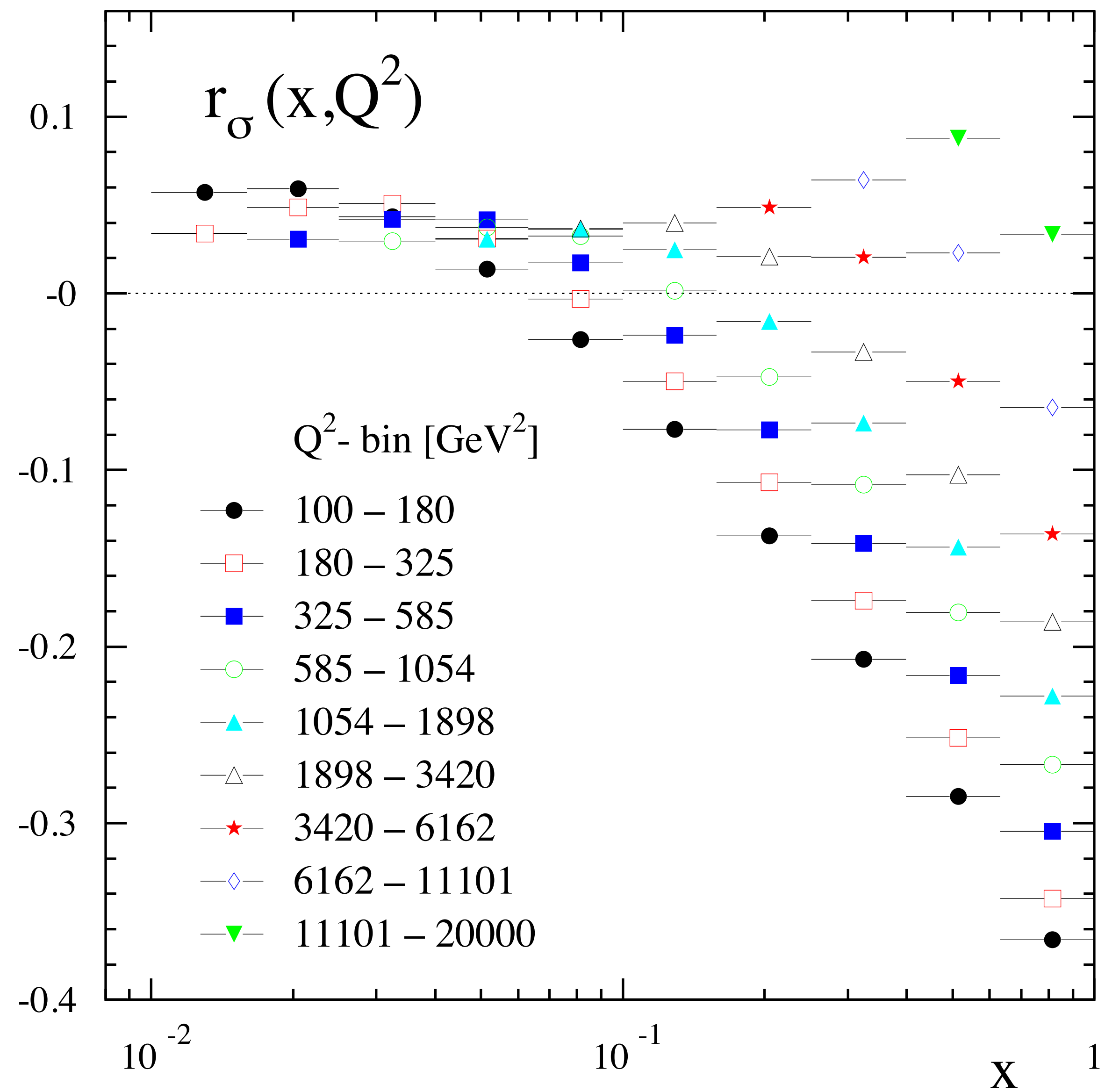


  - LUND string fragmentation: full final state
- Widely used at HERA
- This analysis uses a new version
  - Add **polarised nucleons**

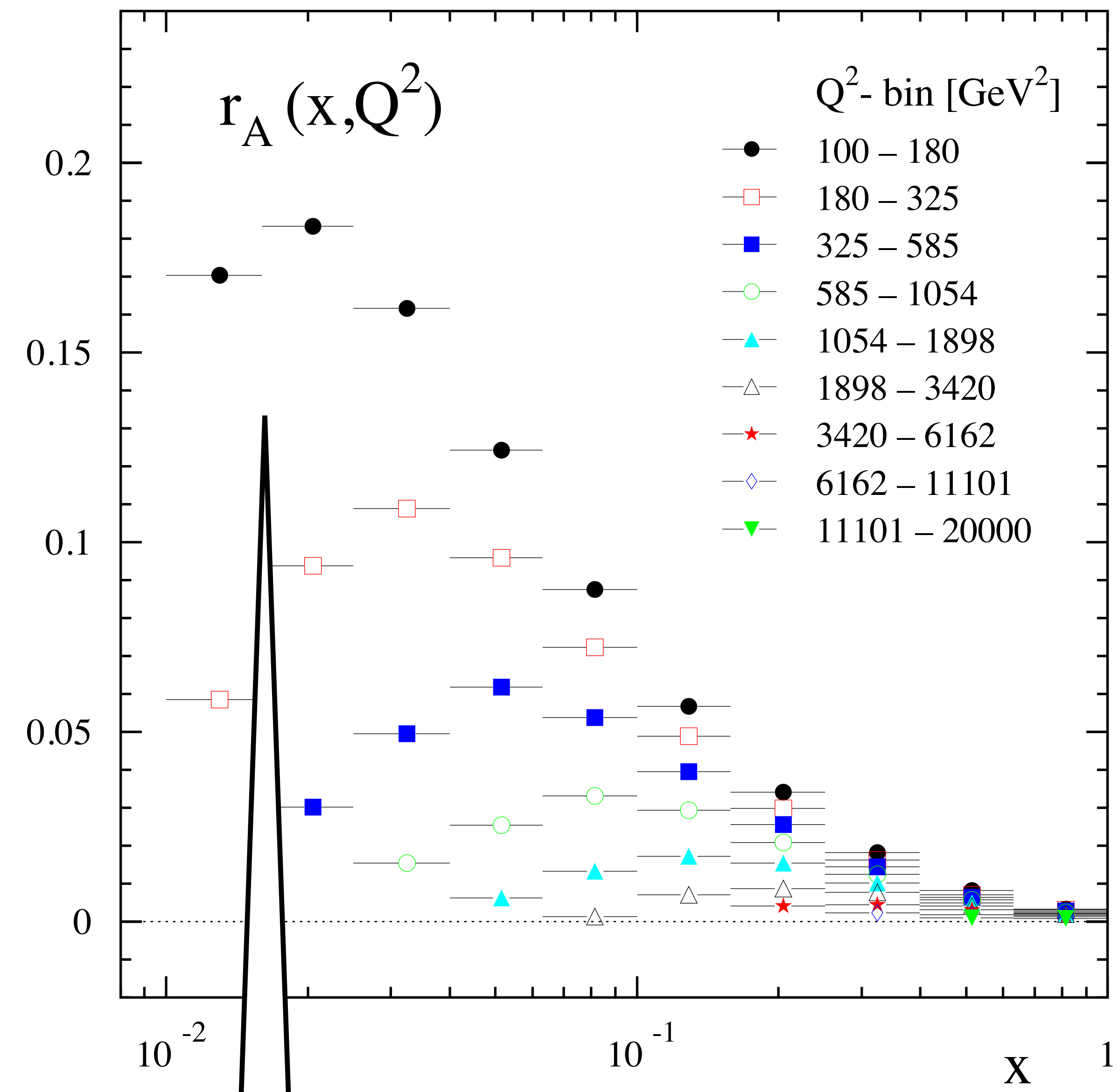
http://wwwthep.physik.uni-mainz.de/~hspiesb/djangoh/djangoh.html

Radiative corrections

$$r_\sigma = d^2\sigma^{W^-,p}|_{\mathcal{O}(\alpha_{em}^3)} / d^2\sigma^{W^-,p}|_{\mathcal{O}(\alpha_{em}^2)} - 1$$



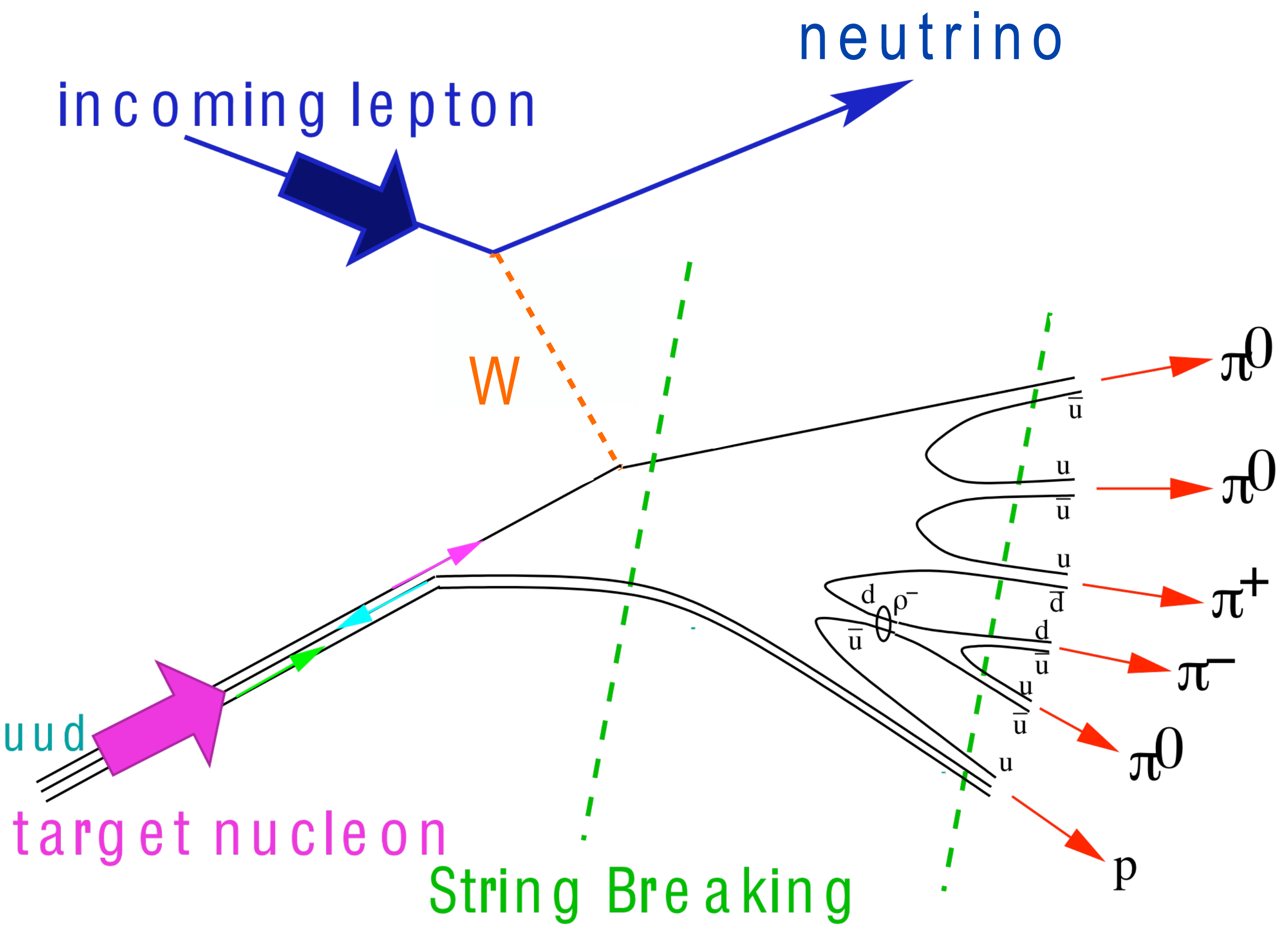
$$r_A = A_L^{W^-,p}|_{\mathcal{O}(\alpha_{em}^3)} / A_L^{W^-,p}|_{\mathcal{O}(\alpha_{em}^2)} - 1$$



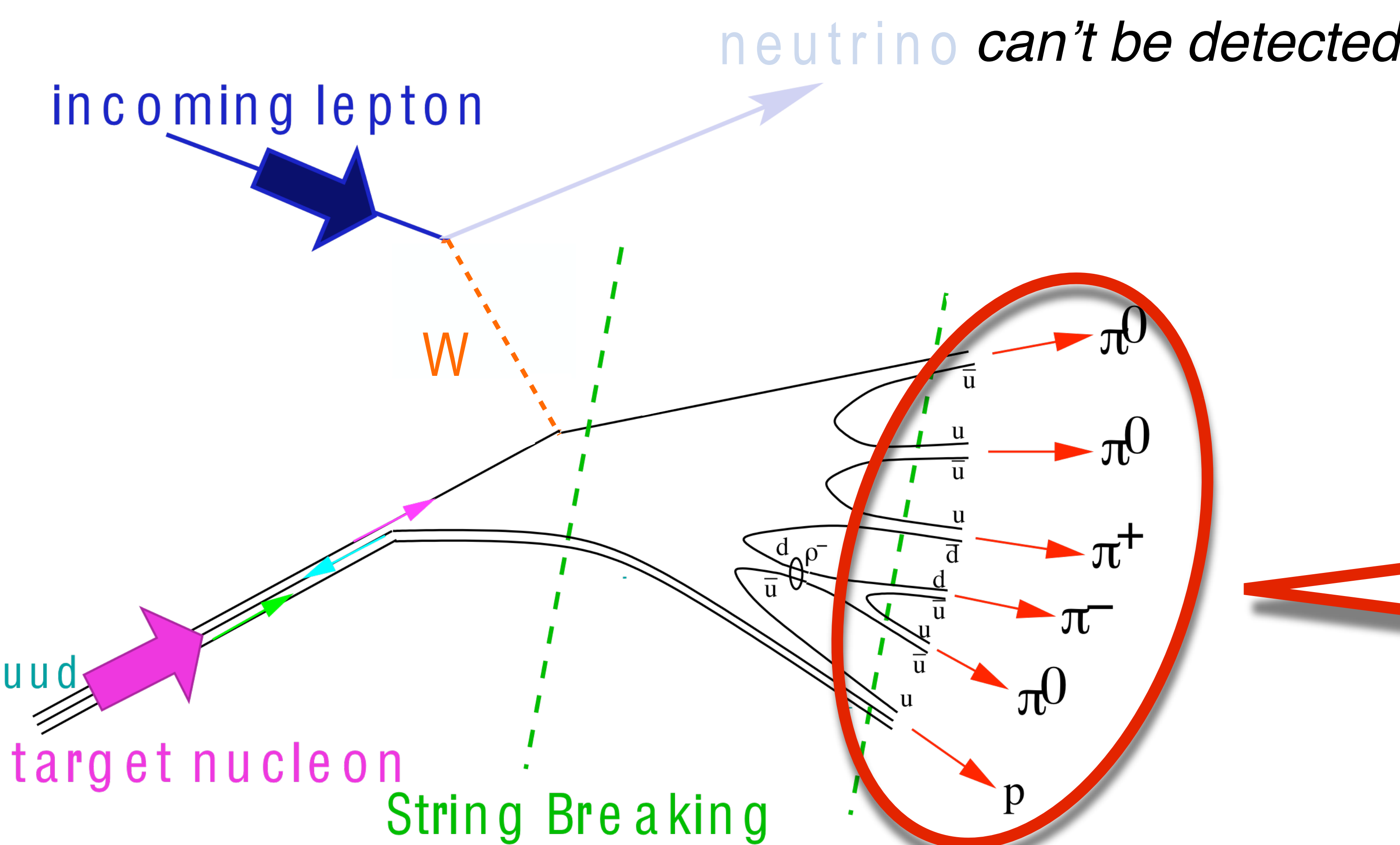
Can expect to be important at **low x** where $\mathbf{A_L^W}$ is **small**

Detector effects and kinematic reconstruction

Jacquet-Blondel method



Jacquet-Blondel method



Reconstruct kinematics from **hadronic final state**

$$y_{\mathrm{JB}} = \frac{\sum_i (E_i - p_{z,i})}{2E_e}$$

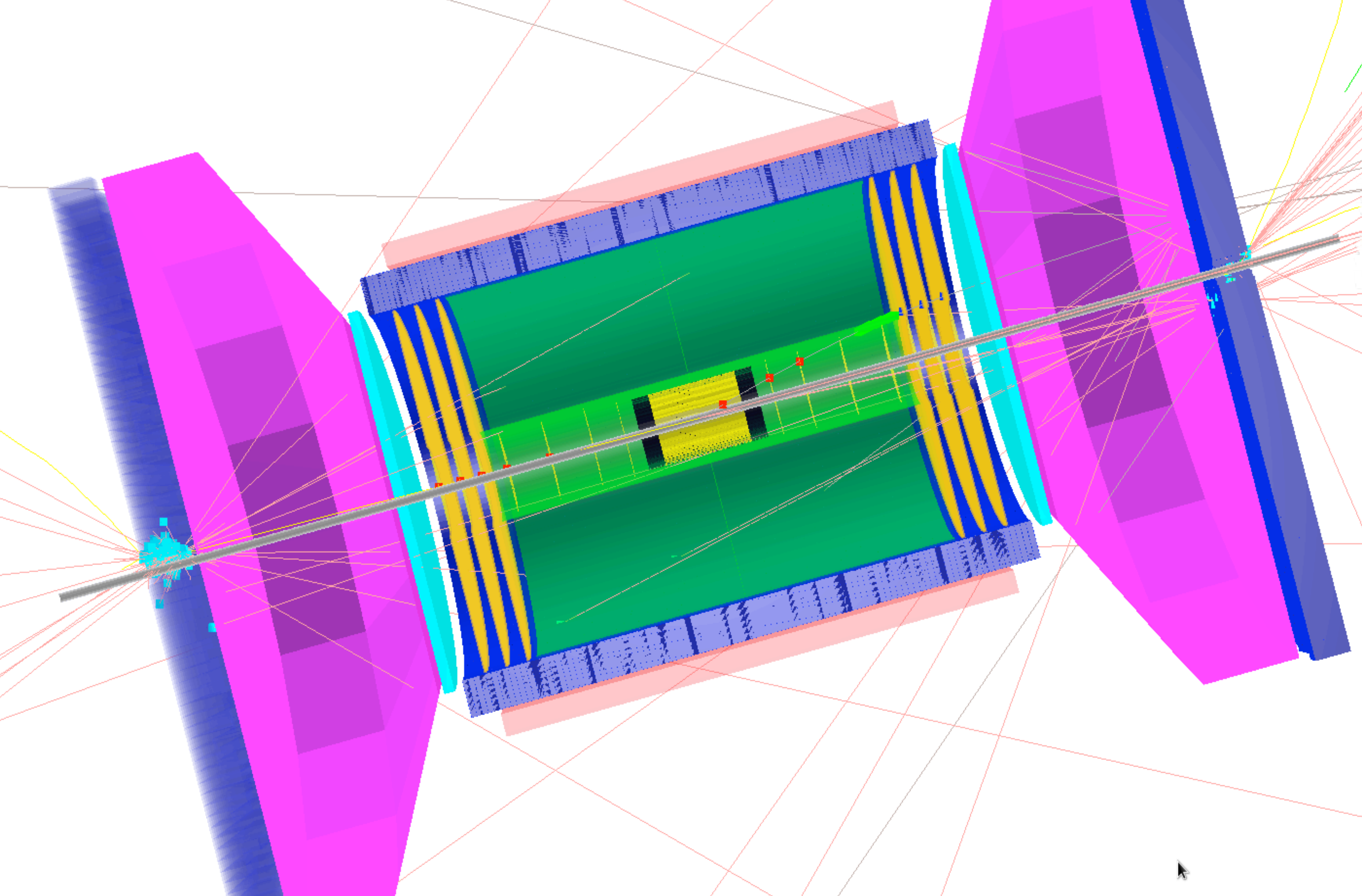
$$Q^2_{\mathrm{JB}} = \frac{p^2_{T,h}}{1 - y_{\mathrm{JB}}}$$

$$x_{\mathrm{JB}} = \frac{Q^2_{\mathrm{JB}}}{y_{\mathrm{JB}} S}$$

$$\left(p_{T,h} = |\textstyle\sum_i \vec{p}_{T,i}| \right)$$

Requires sufficient detector **resolution** and **acceptance**

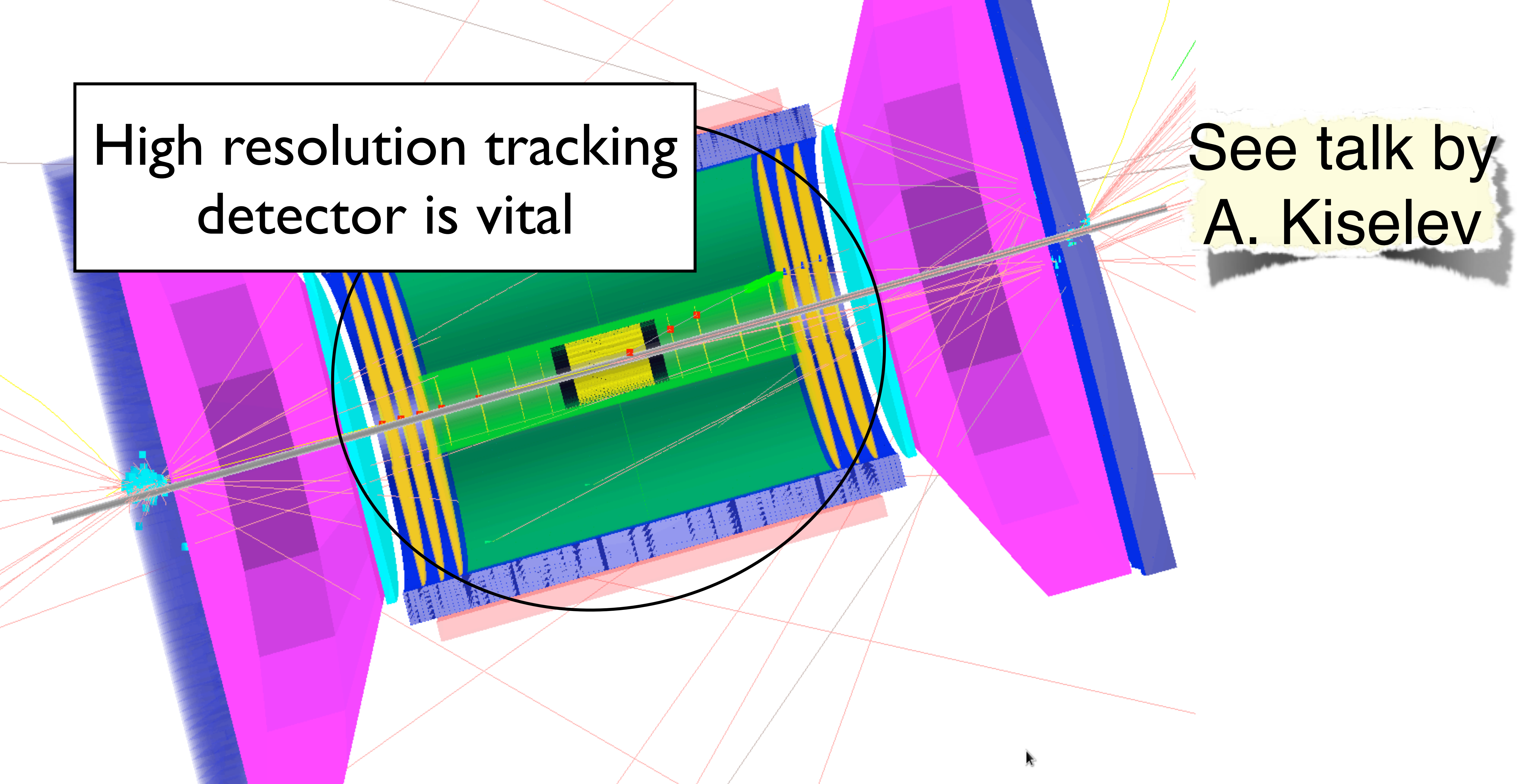
- How well can we do with an EIC?



See talk by A. Kiselev

Geant4 simulation of eRHIC detector

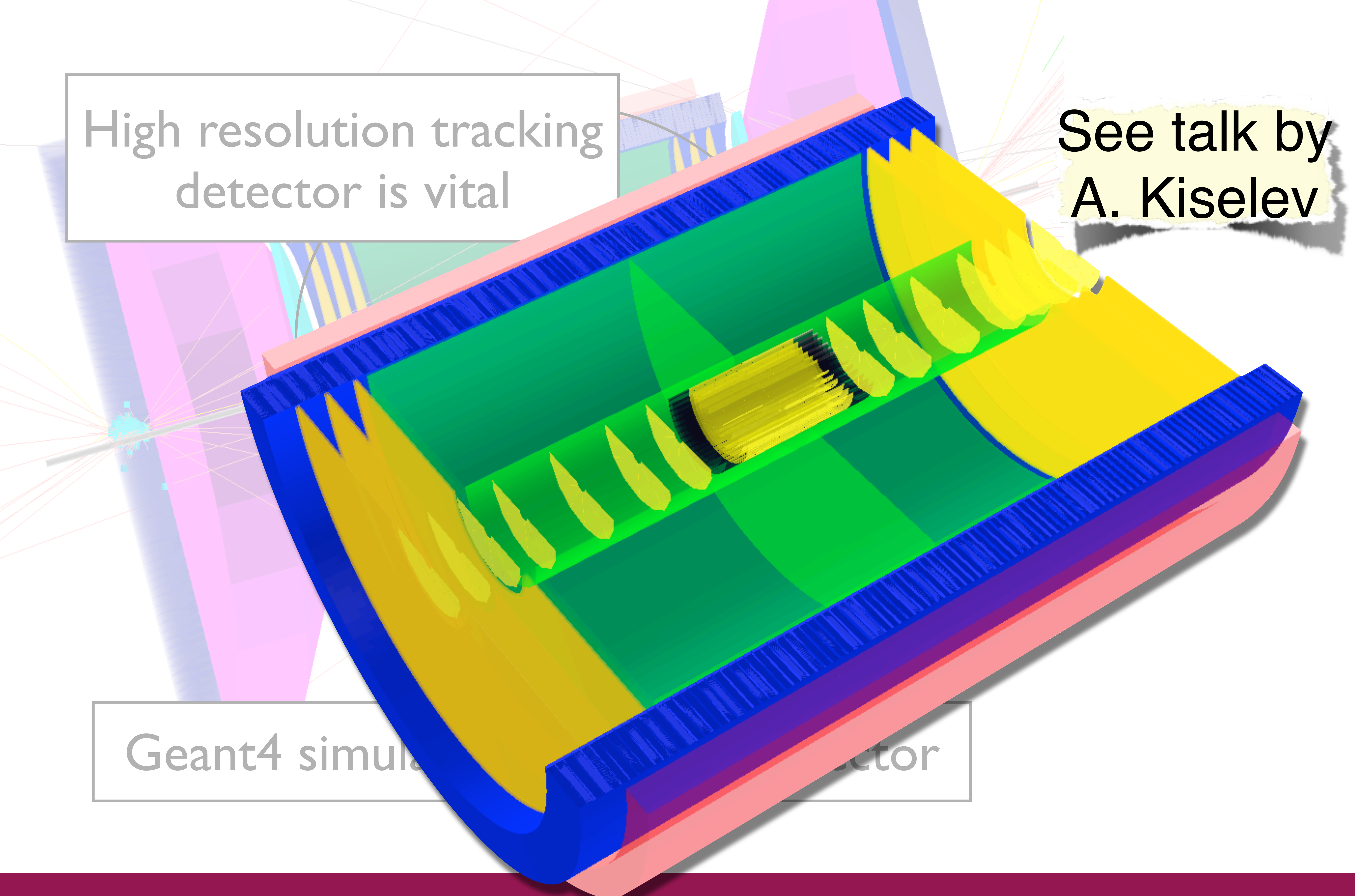
eRHIC detector simulation



Geant4 simulation of eRHIC detector

eRHIC detector simulation

High resolution tracking detector is vital



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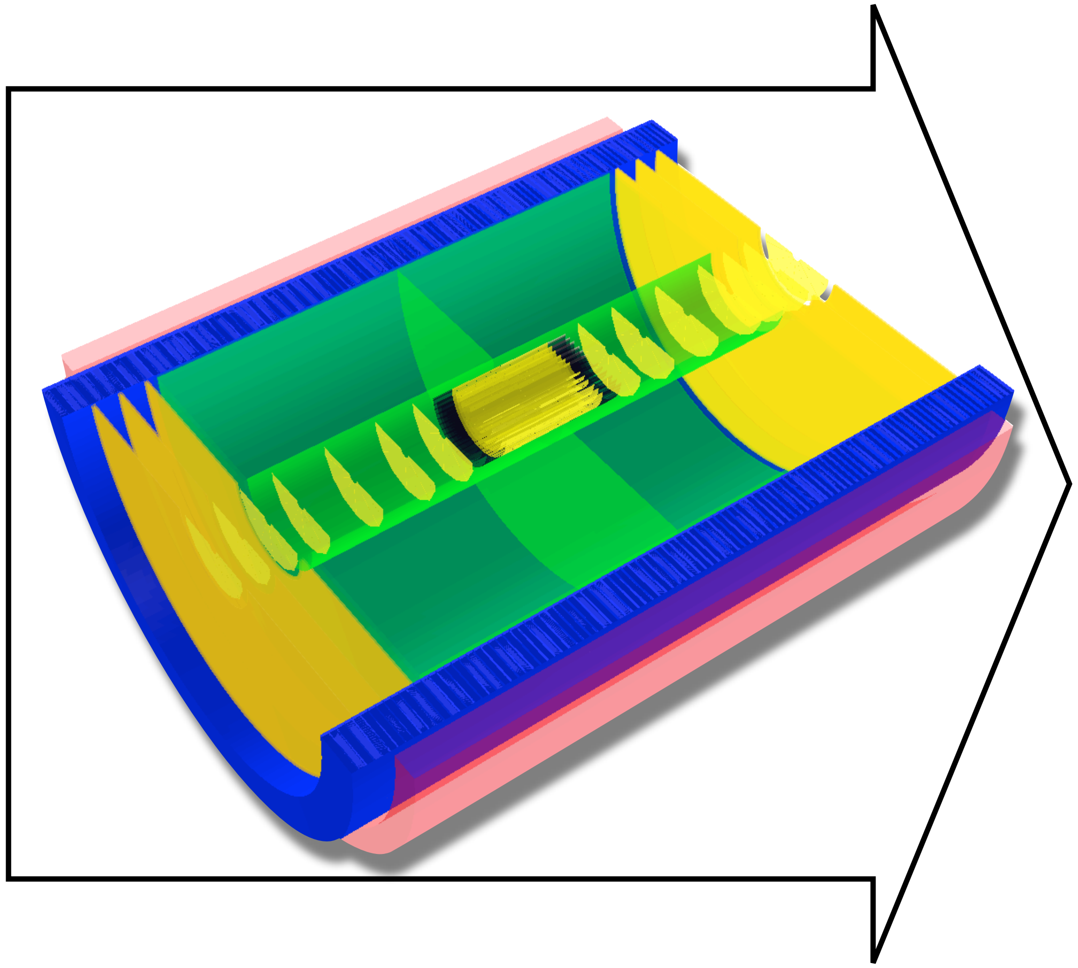
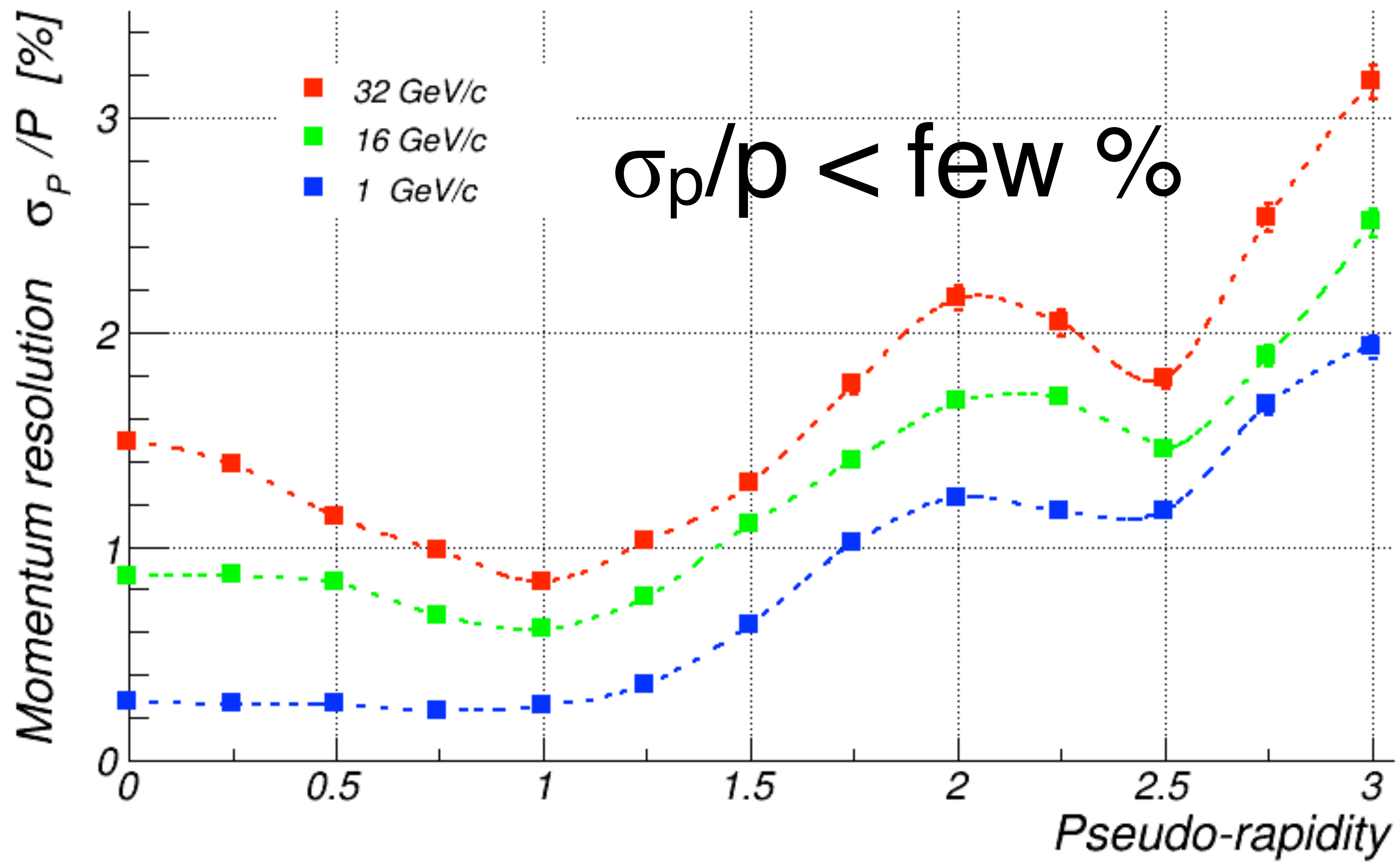
Geant4 simul

ctor

eRHIC detector simulation

Detector performance





σ_p/p < few %

- ECal: $\sigma_E/E = 12\% / \sqrt{E}$, $-1 < \eta < 4.5$
- ECal: $\sigma_E/E = 1.8\% / \sqrt{E}$, $-4.5 < \eta < -1$
- HCal: $\sigma_E/E = 38\% / \sqrt{E}$, $2 < \eta < 4.5$

Better ECal in electron-going direction

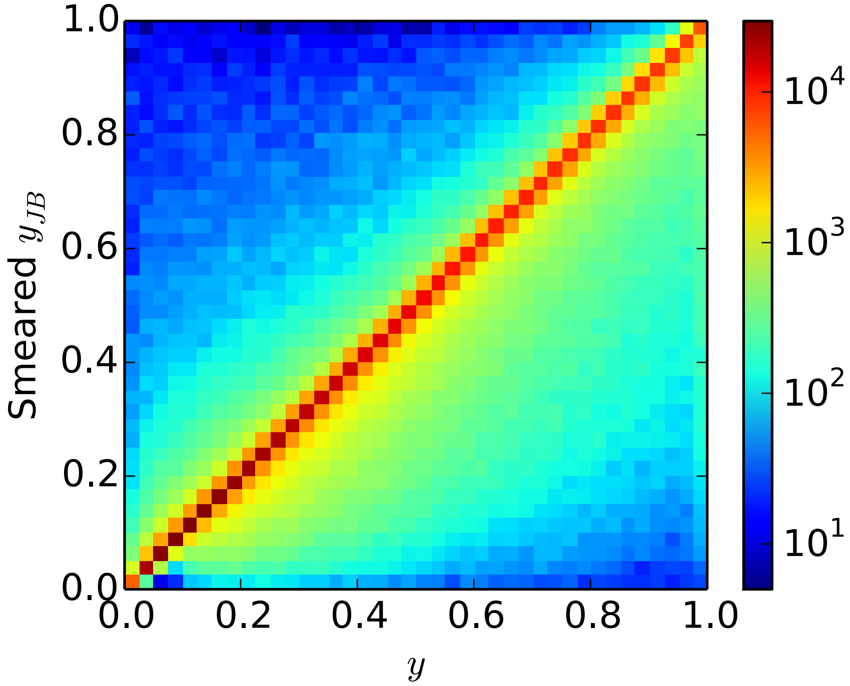
Smear Monte Carlo events with these parameterisations

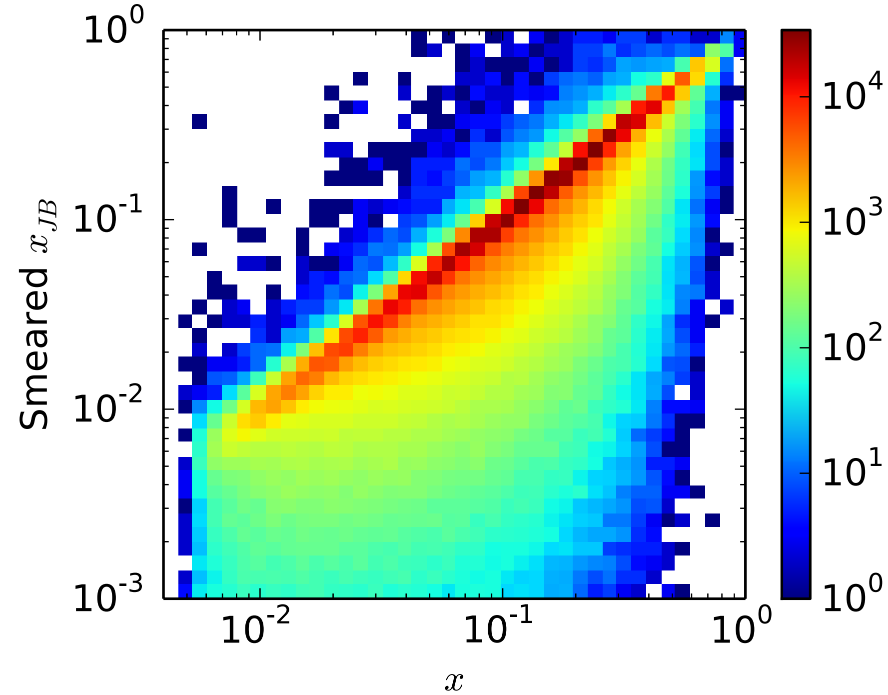
Kinematic reconstruction

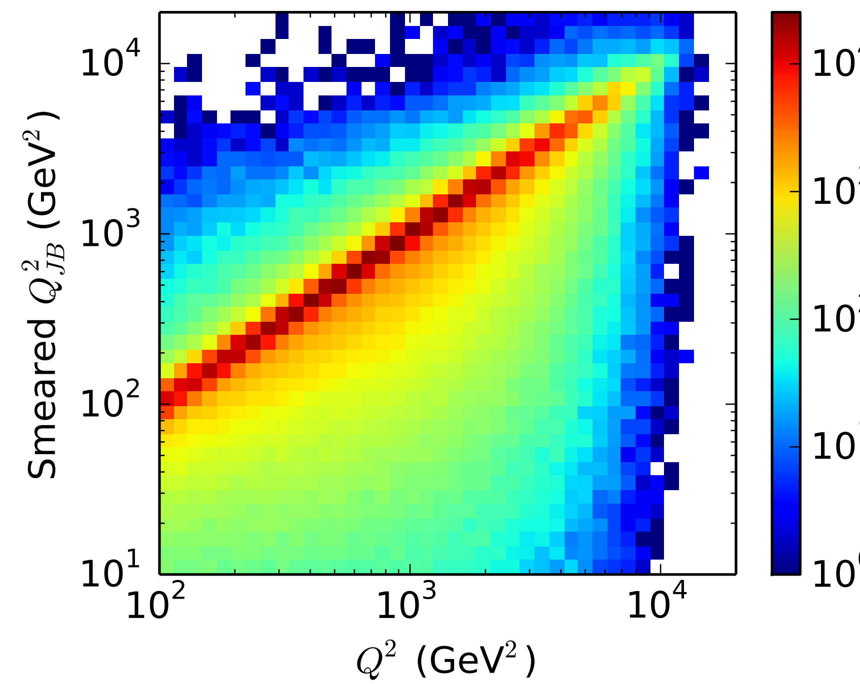
$$y_{\mathrm{JB}} = \frac{\sum_i (E_i - p_{z,i})}{2E_e}$$

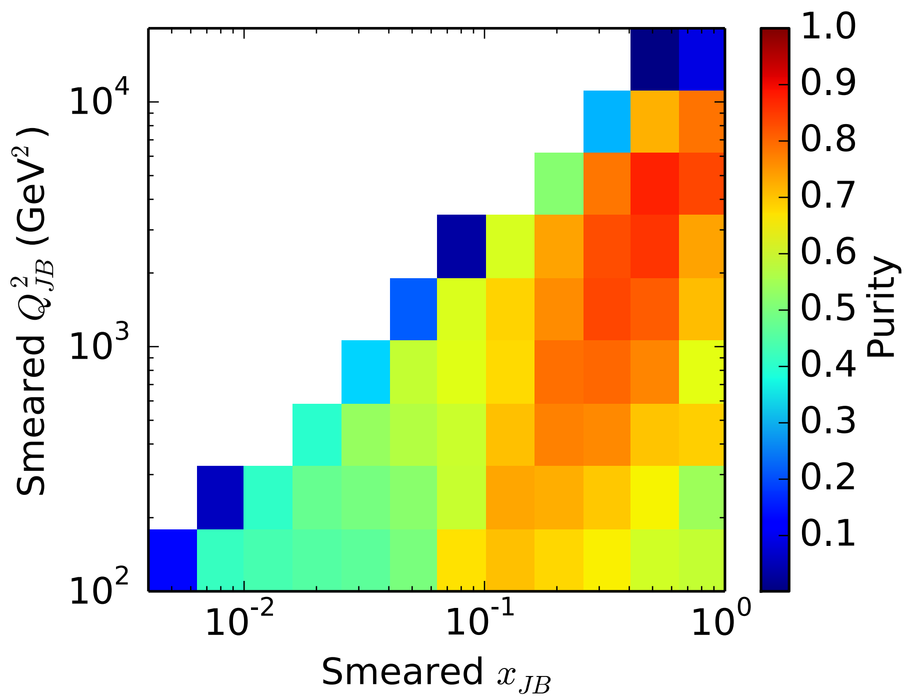
$$x_{\mathrm{JB}} = \frac{Q^2_{\mathrm{JB}}}{y_{\mathrm{JB}} S}$$

$$Q^2_{\mathrm{JB}} = \frac{p^2_{T,h}}{1 - y_{\mathrm{JB}}}, \quad p_{T,h} = |\sum_i \vec{p}_{T,i}|$$







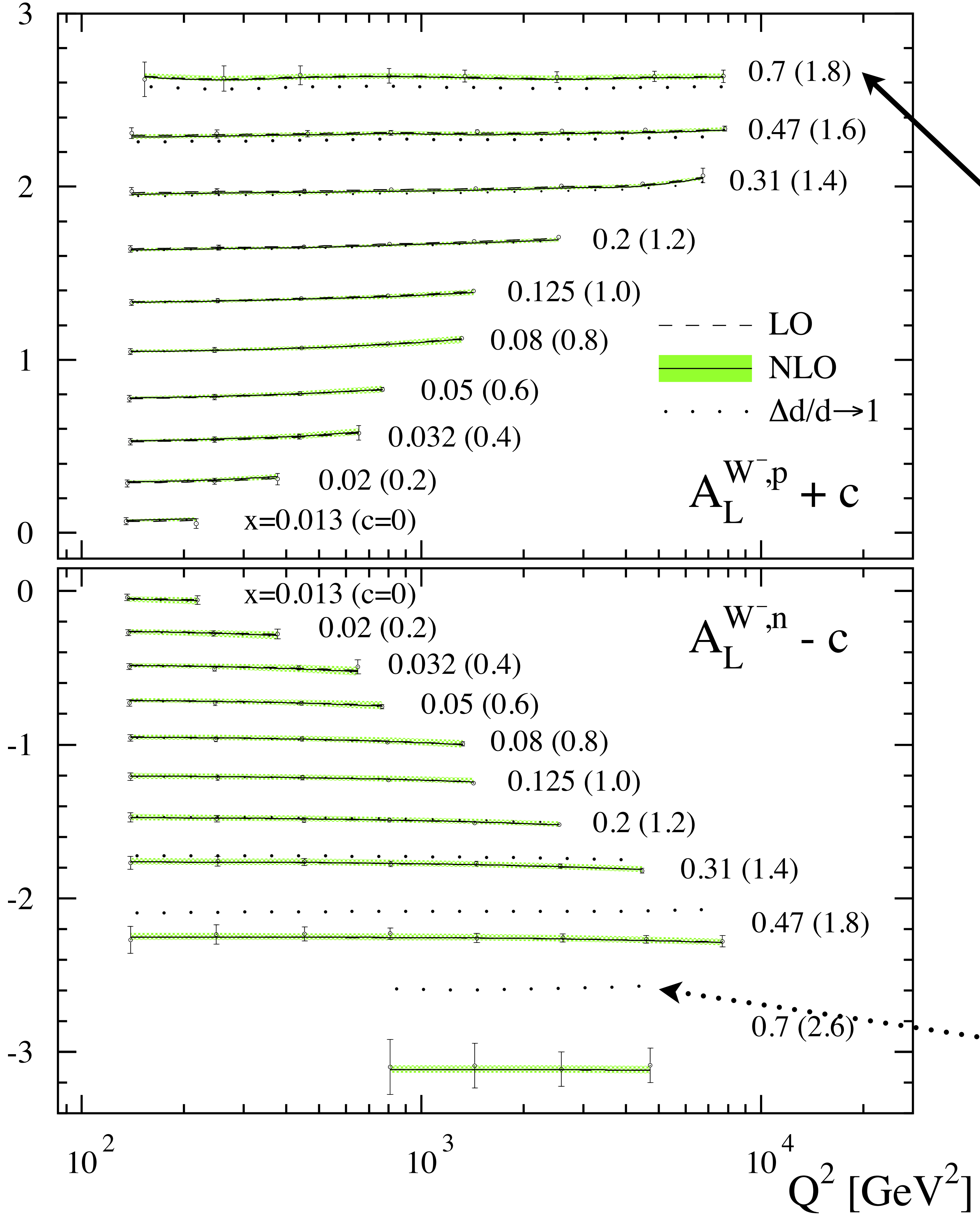


$$\frac{N_{gen} - N_{out}}{N_{gen} - N_{out} + N_{in}}$$

Kinematic construction
under control

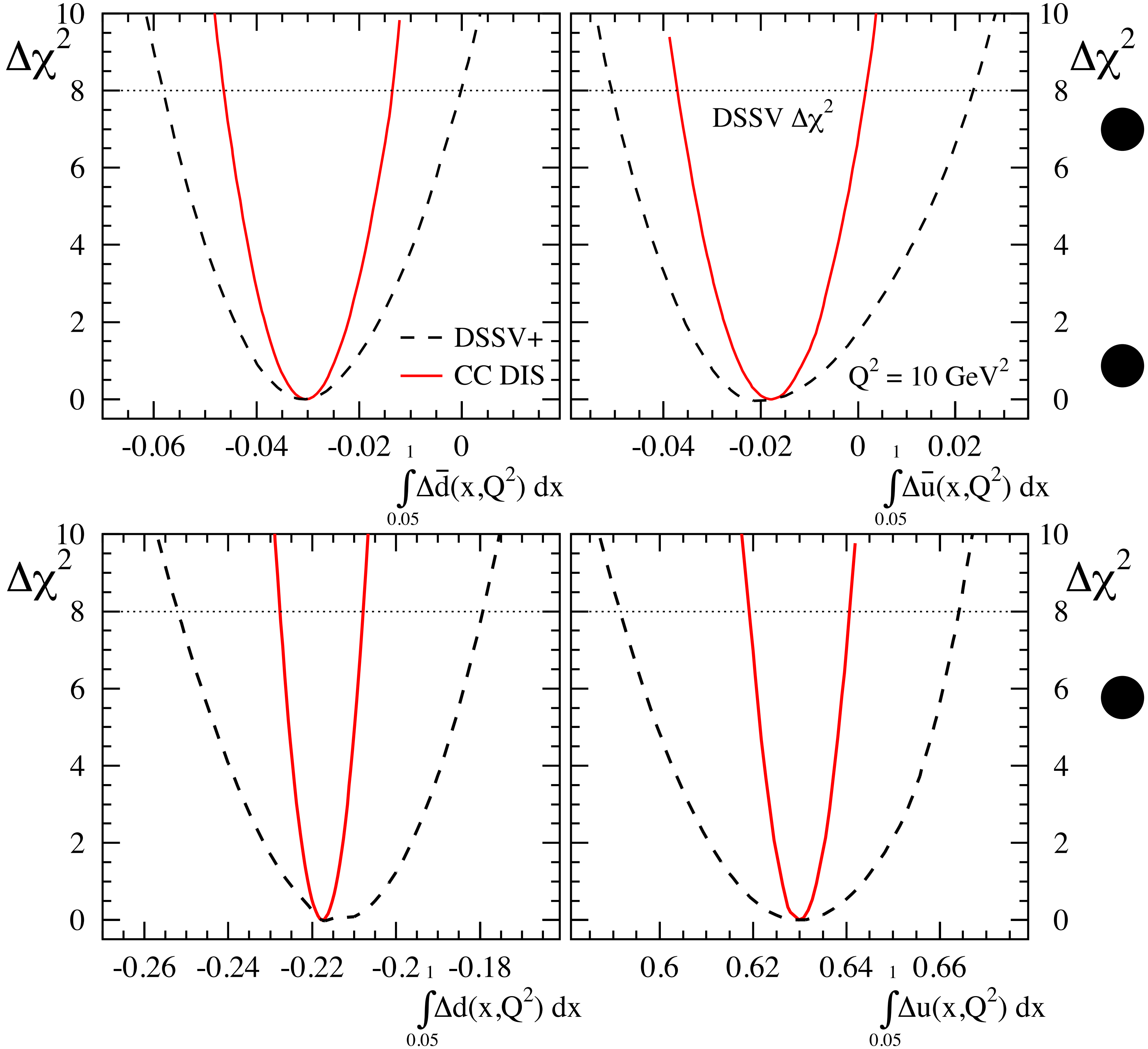
Asymmetry results

A_L^W results



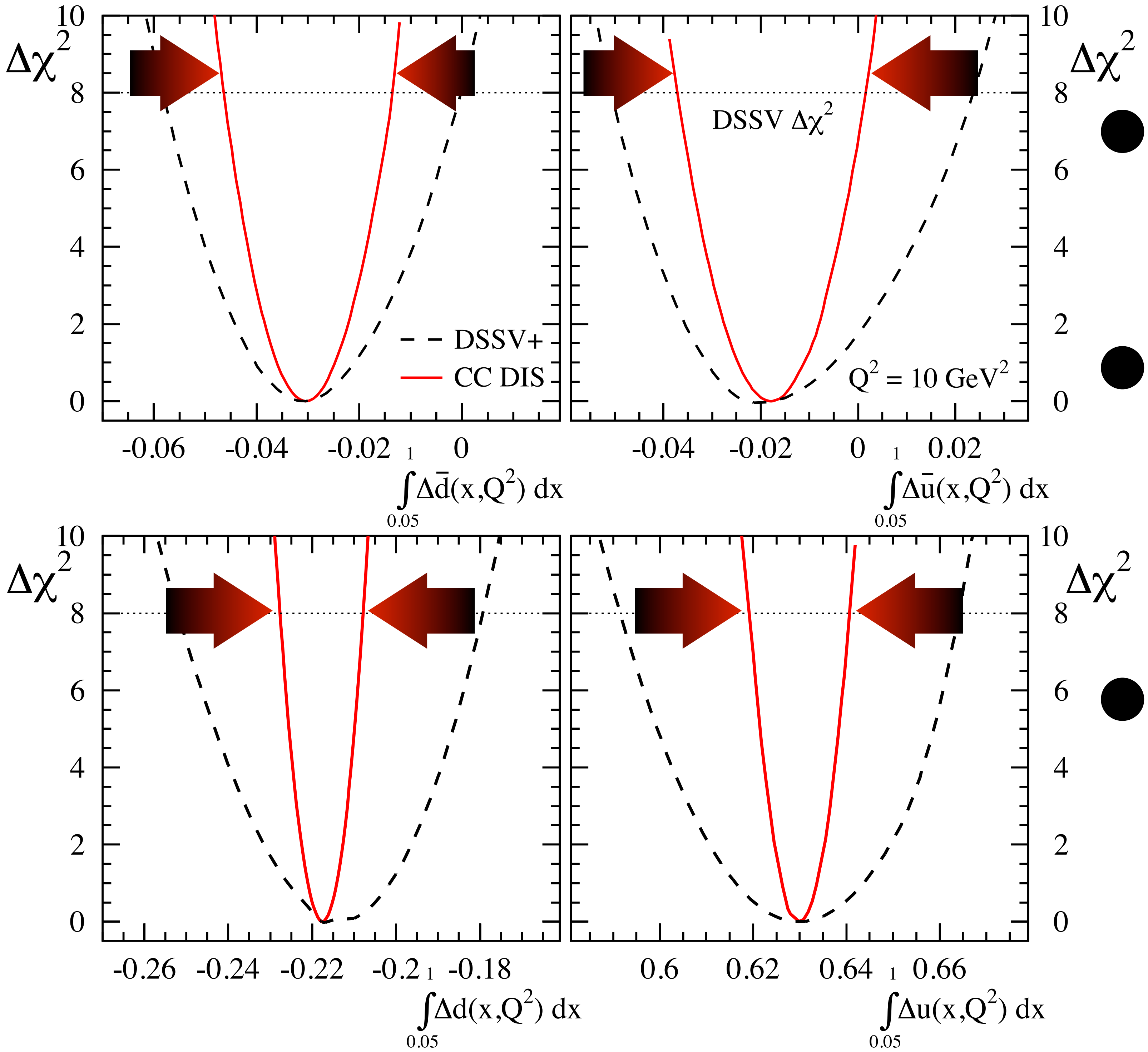
- Large A_L^W at large x ~80%
- NLO effects small
- $\sigma(A_L^W)/A_L^W$ small
  - <~5% for **p**
  - <~8% for **n**
  - ~25% at x limits
- Sensitive to "helicity retention"

Impact on global analyses



- Constrain **u**, **d** & **anti-q** helicities
- Flavour constraint independent of **fragmentation**
- Important cross check on **SIDIS**
  - low Q^2, higher twist effects

Impact on global analyses



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Summary

- **Large A_L^W** in CC DIS
  - yields information complementary to SIDIS
- EIC is **ideal laboratory** to study it
  - Proposed detector is **well suited** to the measurement
- Similar studies may give insights into:
  - **Unpolarised PDFs** at high x & high Q^2
  - **Strangeness**, using CC SIDIS with charm